A CHAMELEON-LIKE CHANGE IN DIEMYCTYLUS.[1]

(PRELIMINARY REPORT.)

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In connection with some work done upon the heliotropic response in the salamander *Diemyctylus viridescens*, it was noticed that under certain conditions the animals changed color within a few hours in a most remarkable manner. The following paper is a report of the results obtained in a study of some of the conditions affecting this color change.

That light and heat are active stimuli in the case of many animals is a well-known fact. It has also been shown repeatedly that not only do these stimuli affect the movements and orientation of the animals, but may, in some instances at least, bring about changes of color as well.

The literature upon this part of the subject is not extensive, so it is impossible at present to formulate any general rule with respect to which these changes may take place. It may be said, however, that there is a remarkable uniformity in the results obtained by different investigators.

In attempting to explain the pigmentation of the salamander, *Salamandra maculata*, Fischel[2] found that the temperature to which the animals were subjected was an important factor. He observed that the larvæ of the salamander which developed in warm water were of a lighter color than those which developed in cold water. If dark-colored larvæ were placed in warm water they became lighter in color, the degree of the change varying with the age of the larvæ at the beginning of the experiment. The newly-hatched larvæ were found, also, to be much more susceptible to the changes in temperature than the older larvæ. As the larvæ became older the effects of the temperature to which they had been subjected tended to become fixed. If light-colored larvæ were placed in colder water, the converse change was noticed,

[1] From the Zoölogical Laboratory of Syracuse University.

[2] Fischel, *Arch. f. Mikr. Anat.*, XLVI., pp. 719–748.

and this also tended to become permanent as the age of the animals became greater.

Flemming[1] observed that the conditions of light as well as of temperature make their impress upon the coloration of the salamander. Animals left in dark aquaria become and remain dark, while those in the light, for example, in white porcelain dishes, become light, the temperature of the water being the same in the two cases.

The recent work of Carlton[2] upon the chameleon *Anolis* gives us even more striking evidence of the part played by external conditions in the coloration of animals. He found that the skin of *Anolis* can be made to assume one of two colors, dark brown or pea green. The brown state for animals in confinement is taken on in daylight and is produced by the outward migration of pigment granules from the bodies of the melanopores into the processes and ultimate branches. This outward migration is accomplished in about four minutes. It may be brought about either by mechanical stimulation of the skin or by an act of the nervous system. The brown state is ordinarily maintained by a tonus established by the sympathetic nerves and dependent upon the stimulation of the nervous end organs in the skin by the light. The melanophores of *Anolis* are not directly stimulated by the light. The green state is taken on in the dark, and is produced by the inward migration of the pigment granules of the melanophores whereby the reflecting ochrophore becomes exposed to the light. This inward migration requires about twenty-five minutes. It may be induced by any means which will bring the melanophores into the unstimulated state.

Experiments upon Diemyctylus.

The material upon which these observations were made was the salamander *Diemyctylus viridescens*. Specimens were collected in the fall of the year and had been kept in the laboratory during the winter in glass jars. The water in the jars was frequently changed and the animals were fed upon raw beef at regular intervals. In the spring observations were also made upon specimens just taken from their usual environment with similar results.

[1] Flemming, *Arch. f. Mikr. Anat.*, XLVIII., pp. 690–692.

[2] Carlton, *Proc. Amer. Acad. Arts and Sci.*, XXXIX., No. 10, pp. 259–276.

When under their normal conditions the salamanders are of a dirty yellow brown color upon the dorsal surface and a lemon yellow upon the ventral surface. Upon both surfaces there are black pigment spots about one half millimeter in diameter. There are also upon the dorsal surface a number of scattered red pigment spots. This description may apply equally well to animals just taken from their native surroundings or which have been kept in the laboratory for a considerable period at the room temperature. Specimens taken at random from the ponds do not vary much in color.

When the animals are exposed to a temperature which is much below that to which they have been accustomed it was found that there resulted a change in the appearance of the skin which would continue as long as the low temperature was maintained. Instead of a dirty yellow, the skin assumed a much darker color, becoming dark brown, dark green or in extreme cases almost black. This change took place in the course of a few hours and remained so long as the animals were subjected to the artificial condition. The amount of change in color which took place as the result of the change in temperature was in a measure a function of the total amount of temperature change. If the change were only a slight one the color response would be correspondingly slight, while if the temperature change were greater the color change would be also more pronounced.

If, on the contrary, the temperature of the water in which the animals were living was raised, it was found that the animals responded to the increased temperature by a lightening of the skin. Under these conditions the yellow in the skin became more pronounced and the darker colors less so. This change also was found to continue so long as the water remained warm. When the water became cold the color of the skin would return after a given interval to what it was at the beginning of the experiment.

Another fact of interest in connection with this color change is that if the temperature of the water be maintained at a constant point and the intensity of the light be changed, the color of the animals will be found to respond in a very definite way. It must be stated, however, that the response in this latter case is less pronounced than that obtained by a change in temperature, and

may indeed be obscured by the action on a change in temperature. If the animals were placed in the dark for several hours they all became darker, if in the light for a number of hours they all became lighter. It was further found that the change in color due to a change in light conditions might be inhibited by contrary changes in the temperature conditions. The following table represents various combinations of light and temperature conditions which have been tested and the results obtained in the coloration of the animals.

Temperature.	In Dark.	In Light.
High,	Ordinary,	Very Light.
Low,	Very Dark,	Ordinary.

By high temperatures are meant temperatures of from thirty-five to forty degrees Celsius; by low, temperatures below ten degrees Celsius.

From the table it is readily seen that we are here dealing with two sets of forces which tend to neutralize each other when applied in opposite directions and to augment each other when applied in the same direction.

The manner in which this change is brought about is the same as that described by Carlton for *Anolis*. Small granules of pigment migrate outward from the large pigment cells along the ray-like processes of the cells when the animal is placed in the dark, thus obscuring the yellow pigment which lies in the deeper layers of the skin. When the animal is brought again into the light the pigment granules again migrate into the bodies of the pigment cells, and the lighter yellow pigment of the deeper layers of the skin becomes visible. The operation is a rather slow one and may occupy an hour or more of time.

In certain animals a condition of permanent darkness was established through a section of the optic nerves. So long as the animal had one or both eyes functional the action of the skin was as stated above. When both eyes are made functionless a marked change takes place. Within a short time the skin begins to darken and within two hours has taken on a dark brown, dark green or black color. The appearance of the animals is similar to that produced by the action of darkness and low temperature. At ordinary room temperatures this change is permanent.

But it is a remarkable fact that in this blind condition the animals are even more than normally sensitive to changes in temperature. If the temperature on the water be raised by any considerable amount the color of the animal changes correspondingly, becoming much lighter. On the other hand if the temperature of the water be lowered they again resume the intense dark color which came on as the result of the operation. These changes in color usually occupy a time of not far from two hours.

The question now arose as to how this color change was controlled. It was at first thought that it must be controlled through the central nervous system, but the following experiments seem to throw doubt upon such an explanation.

Section of the Spinal Cord. — It has been shown above that section of the optic nerves brings about a most remarkable result in the coloration of the salamander. Now if the impulses effective in bringing about this change pass to the skin through the brain and spinal cord we should find upon section of the spinal cord that the parts of the skin supplied by nerves arising from the spinal cord below the cut should respond in a different way from those parts of the skin supplied by nerves arising from the spinal cord above the cut. In order to test this possibility a number of salamanders were operated upon in the following way. The spinal cord was completely sectioned at the level of the third or fourth thoracic vertebra while under the influence of ether. At the same time other individuals were subjected to the same anesthetic for the same length of time to assure us that any change in the appearance of the animal was not due merely to the effect of the ether. After the animals had been given opportunity to recover from the shock effects of the operation, no change being found in the color of the skin as the result of the first operation, they were again taken and subjected to section of the optic nerves. Following this operation, usually within a period of not more than two hours there was found that same remarkable darkening of the skin which has already been described. And this darkening of the skin involved the whole dorsal surface of the animal and not merely that part of the skin controlled by nerves arising either above or below the section of the spinal cord. From this it is seen that the nervous impulses

must have some other path of communication between the optic centers and the pigment cells of the skin than that furnished by the brain and spinal cord. It might be possible that the skin itself could furnish such a channel of communication, but a more reasonable means would seem to be through the the sympathetic nerves. In this our results agree with those of other observers.

There is also in the vicinity another variety of *Diemyctylus viridescens* known as *miniatus*. This is a land form and is of a vermilion color. It possesses few or none of the black pigment spots and apparently very few pigment cells. A series of experiments was also carried out upon this form but in no case was there any change of color noticed after section of the optic nerves.

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